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A New Learning Environment through Improved Learning Objectives in an Introductory Solid Mechanics Course

Christopher R. McGann[1]
[1] *Department of Civil and Natural Resources Engineering, University of Canterbury, Christchurch, New Zealand*
Corresponding Author Email: christopher.mcgann@canterbury.ac.nz

STRUCTURED ABSTRACT

CONTEXT
Learning objectives are a commonly used way of conveying the important concepts in a particular course to the students. In practice, such learning objectives are often provided in the course outline but are not explicitly emphasised by the instructor during lectures. It is also common in practice that the learning objectives are based around vague verbs (e.g., understand, appreciate) that are difficult for students to use in self-assessment of their learning. Educational research has shown that neither of these common approaches for learning objectives are optimal, as students have been found more likely to reach expectations when learning objectives are explicitly communicated and emphasised, and are written around action-oriented verbs.

PURPOSE
The primary research question addressed by this paper is: How does the development and explicit communication of action-oriented learning objectives affect student learning, instructor teaching, and the classroom experience in an introductory solid mechanics course and how do these learning objectives support a diversity of learning styles?

APPROACH
This study is conducted via two primary means. For the instructor side of things, an autoethnographic approach is adopted in which weekly journaling is used to reveal insights into the process of lecturing, preparing for lectures, and writing assessments. For the student learning side of things, official and unofficial student feedback is the primary means of response.

RESULTS
The results of this study indicate an improved channel of communication between the instructor and students that better enables the students to identify which parts of lectures are most important. The other key observation is that this approach allowed students to view the learning objectives from their own diverse learning perspectives/styles, as the adopted objectives represent concrete actions that students should be able to perform and they were free to study and understand these objectives from a variety of perspectives.

CONCLUSIONS
The newly adopted approach to learning objectives has produced results in line with similar previous case histories, particularly in regard to the benefits to the student learning experience and the general improvement in student performance relative to previous years. The autoethnographic approach to the instructor experience in this study has revealed some of the personal and professional benefits of the new approach, primarily through an improved focus on key ideas and concepts during lecture and assessment preparation.

KEYWORDS
Learning objectives; autoethnography; tertiary engineering education

Introduction

Tertiary students in civil engineering are commonly faced with a daily schedule full of lectures on a relatively broad range of topics as part of a core curriculum prescribed by their college or department. Ideally, all students in these programmes would have unlimited time and mental resources to devote to their studies and would understand the intricacies of each topic and lecture perfectly. Realistically, tertiary students do not all have the resources necessary to achieve these lofty goals and are often driven by questions such as, “What do I *really* need to know from this lecture?” or “How can I be best prepared for the final exam?” Inspired by these questions, I implemented a new approach to learning objectives in my introductory solid mechanics course for civil engineering students in Semester 1 (February-June) 2018. This paper discusses these learning objectives and how their development and explicit communication affected student learning, instructor teaching, and the classroom experience.

In previous years in this course, I provided learning objectives in the course outline to convey key content and important outcomes, but I had never put much emphasis on using them any further. My former objectives also tended to be quite general and based upon vague verbs. For example, one of the learning objectives used in a previous year was stated as, “Understand stresses and strains in beams and how they arise from a given load.” While this conveys a general sense of what is covered in one of the course modules, it is difficult for students to self-assess their learning as it is difficult to know if one truly understands something or to define what *understand* means in the context of the course. The learning objectives that I developed for the 2018 instance of this course were inspired by the course design guidelines of Welch et al. (2005) and the excellent example study in the context of geotechnical engineering provided by Fiegel (2012), and describe explicit tasks that the students should be able to do at the conclusion of each learning module. In contrast to previous years, I also explicitly communicated and emphasised these new learning objectives throughout the teaching term.

My motivation for this revised approach was associated with two key student outcomes: (1) students can better self-assess their learning of the material, i.e. they either feel comfortable accomplishing the tasks outlined in each objective or they don’t; (2) the expectations for competency and mastery of the course material are much better communicated, allowing students to better focus on the core concepts during lectures, tutorials, and self-study. It is also expected that though the revised learning objectives emphasise a set of actionable tasks, they de-emphasise a strict path towards learning and achieving these tasks, thus potentially supporting a diverse range of learning and study styles. The effectiveness of the revised approach in terms of these student outcomes is assessed in terms of student feedback and achievement levels from the solid mechanics course in the most recent year (with new learning objectives) as well as the previous year of the same course that used the traditional approach to learning objectives. This study also investigates the effects of the change in approach on my own experience in the course in regard to tasks such as planning, lecturing, and assessment design. To this purpose, an autoethnographic approach (Ellis, 2004; Chang, 2008; Ellis et al., 2011) is adopted where my regular journaling during the teaching term is used to find insights into changes in my thought processes, actions, interactions with students, and overall feeling for the course.

Course Background

The course used to support this study is an introductory solid mechanics course required for first-year civil engineering students. This course is structured with four 1-hour lectures per week with a 2-hour tutorial on the fifth day. There is also a laboratory exercise and report, but this part of the course is not the focus of the current study. The lectures are used to deliver course material to the students, with the typical lecture consisting of a mix of underlying theory, problem solving techniques, and worked example problems and applications. In the tutorial sessions at the end of each week, students are given practice problems that relate to the material covered during the preceding lectures and break up into groups to work through them under the guidance of the lecturer and a team of tutors. This guided practice component is the primary purpose of the tutorials. The course is offered once per year, with an average of about 235 enrolled students.

This course has been broken down into a series of learning modules that group similar topics together and are arranged in a progression through the semester. The learning modules for this course are provided in Table 1. The current study concerns the second term of the course for which I was the responsible lecturer. This term covers Modules 4-7 and the assessments for this part of the course are comprised of an assignment that is approximately 10% of the final grade and covers Modules 4-6, and the final exam, which is 40% of the final grade and covers all four second term modules as well as some fundamental material covered in the three first term modules, e.g., shear and moment diagrams.

Table 1: Learning modules for introductory solid mechanics course used in this study.

Number	Learning Module
1	Stress and Strain
2	Pure Bending
3	Beam Bending
4	Shear Stresses in Beams
5	Transformation of Stress and Strain
6	Torsion
7	Flexural Deflections of Beams

Learning Objectives and Approach

The new learning objectives for this introductory solid mechanics course were developed based on the existing course content built around the learning modules of Table 1. Because this is a core course taken by all civil engineering students, the content had to remain relatively static to avoid disrupting the overall programme of study, but this wasn't an issue as content was already appropriate. The framework used to develop these learning objectives follows the scheme of Table 2 (adapted from Fiegel, 2012), in which, following the approach of Bloom et al. (1956), increasing mastery of the topic is indicated by achievement levels with higher numbers and the learning objectives are presented in terms of actions that it is expected students will be able to perform after the lectures, tutorials, assignments, and self-study associated with each module.

Table 2: Achievement levels and actions for general learning objectives (after Fiegel, 2012)

Achievement Level	Example Actions
1 Knowledge	define; describe; identify; list; name
2 Comprehension	explain; paraphrase; summarise
3 Apply	calculate; determine; implement; solve
4 Analyse	compare; classify; organise; prioritise
5 Synthesise	create; design; devise
6 Evaluate	critique; defend; justify; judge

Examples of the specific learning objectives developed for Module 4 are provided in Table 3. These learning objectives were presented in the lectures at the beginning and end of each module. The discussions at the start of the modules took place as part of a preview session where I discussed what will be covered in each new module and how it relates to previous modules, and the corresponding discussions at the end of each module took place as part of a review session where I summarised the important concepts and began to look forward to how things fit into subsequent modules of the course.

The module learning objectives were also posted to the course website along with a brief description of how the interpret the achievement levels. The document posted to the website also indicated which learning objectives from previous modules are relevant to the current module. For example, in order to achieve the Module 4 learning objectives listed in Table 3, students will already need to be comfortable with (or be working towards comfort with) previous learning objectives from Modules 2 and 3 such as calculating the location of the neutral axis for a cross-section, calculating the second area moment for a cross-section, drawing shear and moment diagrams, and calculating bending normal stresses in beams. This kind of information was explicitly communicated with the learning objectives for each module in order to link the new material to the overall flow of the course.

Table 3: Module 4 Learning Objectives: Shear stresses in beams

Action	Objective (Achievement Level)
Define …	shear force; shear flow; shear stress; flange; web; shear centre (1)
Explain …	how bending produces internal shear stress in a beam; why connections (e.g. nails, welds) are required for built-up cross-sections; relationship between longitudinal and transverse shear stress (2)
Calculate …	first area moment; maximum flexural shear stress; shear flow or shear stress at connection of built-up sections; location of shear centre for a cross-section (3)
Prepare …	a shear flow diagram for a thin-walled cross-section (3)
Assess …	the factor of safety for a given beam section for both bending normal stress and flexural shear stress; the factor of safety for a specified welded or nailed connection in a built-up cross-section (4)
Design …	a rectangular beam section for both bending normal stress and flexural shear stress; a welded or nailed connection in a built-up section (5)

Student Feedback

The general feedback from students in regard to the course learning objectives was positive and reinforced some of the motivating factors that led me to adopt this new approach. Some examples of this feedback are provided below in the form of direct quotes from optional text-based comments in the formal teaching survey questions administered by the university.

> *I liked having the learning objectives for each module as it helps gauge my level of understanding.*

> *The detailed learning outcomes offer very good self-reflection on where I stand with the material.*

> *So well planned!!! Starting new topics with the learning objectives (and going through them at the end) was a cool idea because I love lists.*

The student quoted below provided some constructive feedback in regard to the learning objectives, indicating that I could be even more explicit in my communication.

> *The learning objectives were good. Maybe you can refer back to them more frequently, e.g., when doing an example explicitly state that this is learning objective #3. That way they are always on our minds.*

Informal discussions with students indicated similar outcomes. Items of note from these discussions are provided below to reinforce the feedback obtained from the formal surveys. Some students indicated that they appreciated how my approach didn't emphasise a rigid set of rules for problem solving (i.e. a "cookbook" approach).

> *Not everyone that I know used the learning objectives, but the people who did use them really like them.*

> *I found the learning objectives were really useful when studying for the final exam. I could go through my notes and see which parts were the most important and work on the things that I didn't know as well.*

The formal student feedback also comes in the form of numerical scores to a general set of questions used in all university courses. These scores are given on a 1-5 scale, with the numbers corresponding to a spectrum from *strongly disagree* (1) to *strongly agree* (5). The feedback from these scores is not as specific as the optional comments, but the response rates are much higher. For example, 90% of students responded to the generic questions in 2018, where less than 5% provided written comments. Table 4 shows the numeric survey scores for the 2017 and 2018 instances of the solid mechanics

Table 4: Teaching survey scores in solid mechanics course in 2017 and 2018

Year	Well Organised	Communicates Well	Stimulated Interest	Good Attitude	Overall Effective Lecturer
2017	4.41	4.21	4.23	4.49	4.37
2018	4.57	4.53	4.49	4.69	4.63

course. As shown, the scores increased in all categories. While it is impossible to link this to the modified learning objective approach taken in 2018, these scores are suggestive that student satisfaction increased across the two years, and this increase may be due in part to the change.

Student Achievement

Similar to the numerical teaching survey scores discussed in the previous section, it isn’t possible to state that any change in student achievement from 2017 to 2018 has anything to do with the modified learning objective approach, however, it is interesting to note how the overall course grades shown in Table 5 changed across these years. These results indicate that the largest change occurred with students at the A and B level and that the percentage of students receiving C and lower grades was largely unchanged. Looking further into the numbers, the largest increase in 2018 (+9%) was at the A-level while the largest decrease (-8%) occurred at the B level. Again, noting that many different factors have a role in student achievement, this net movement towards higher grades by students at the B level and the corresponding lack of change at lower achievement levels suggests that students already at higher achievement levels benefited the most from the differences in the course across these two years, and it is possible that the modified learning objectives contributed here.

Table 5: Percentage of students in different grade bands in 2017 and 2018.

Grade	2017	2018
A	16%	28%
B	50%	37%
C	27%	28%
D	8%	8%

Instructor Outcomes

My primary motivations to adopting the revised learning objective approach discussed in this study were related to student outcomes, but in order to provide further learning into the topic I maintained a teaching journal throughout the term where I kept note of my own thoughts. Through this journaling, I have identified the benefits and challenges I encountered while implementing my newly adopted approach for the first time. Though my own experience is unique to a certain degree, I think that these instructor-based outcomes offer a good counterpoint to the student-based outcomes discussed previously, and anticipate that other instructors may benefit from a summary of my experience.

Having taught this course in previous years, the workload associated with course planning and lecture preparation for the 2018 course would have been minimal had I maintained my previous approach. Implementing the new scheme increased this workload somewhat, as it required the development of the actual learning objectives and achievement levels for each module. This increase was minor in practice, and I found the process of working out the objectives to be quite beneficial as it required me to think carefully about the course well in advance of the lectures and identify the critical aspects of the material. Through this process I was subsequently better able to plan the overall progression of the lectures, as well as the conceptual progression through individual lectures.

One specific example of how my teaching changed is in my approach to derivations of concepts and formulas. Through the creation of the learning objectives I decided that the ability to perform these derivations was not a key objective. While it is important to understand the fundamental concepts and assumptions that lead to the equations we use in solid mechanics, the students will never be asked to derive anything outside of academia. I realised when planning my lectures that the time I devoted to performing derivations implied an emphasis on derivations that was not reflected in the new learning objectives. In response, I changed my approach to emphasise the critical assumptions and key steps and de-emphasise the mathematical details (full derivations were posted to the course website for interested students). This modification reduced the lecture time spent on derivations without losing the key outcomes, and gave me more time to cover the use of the derived equations in problem solving applications, which is more in line with what these students will be doing in the future.

The other main observation that I made while going through this revised course for the first time was that writing the assessments was much simpler than in previous years. Having already gone through the exercise of explicitly defining tasks and associating these with achievement levels, all I needed to do when writing the assignment and exam was to come up with questions that would allow me to fairly assess whether the students had achieved the learning objectives. The overall process was not that different than in previous years, as I have always known which learning outcomes I wanted to assess, but having the listed objectives, and having communicated and emphasised these to the students, seemed to make the process simpler and I would recommend this approach for this reason alone.

Conclusions

Student feedback, student achievement, and my own observations made during lectures and course planning indicate that the development, emphasis, and explicit communication of actionable learning objectives can make a positive change in tertiary engineering courses. From the student point of view, this study indicates that the new approach to learning objectives was well received by those students who used them, and that they were particularly useful for the purposes of self-assessment of learning during the course and in the exam study period after lectures ended. Though a definitive conclusion cannot be made from the student survey scores and changes in overall grades with only two years of data, the preliminary results presented here suggest a positive change in the student experience (as expressed through their perception of my performance as a lecturer) and that the largest change in student achievement was evident at the higher achievement levels. Informal feedback from students indicated that there was also a general sense of appreciation for how the new approach allowed for a diversity of learning styles, but this was not frequently cited.

From the instructor point of view, I found that the development and implementation of the modified approach to learning objectives required a bit of work up front and likely some continual adjustment in future years, however, this effort had benefits beyond the positive student outcomes. The process of developing the learning objectives led to improved lecture planning and greatly streamlined the task of writing and marking assessments. I strongly recommend the use of a similar approach in any course.

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